AN EVALUATION OF OUTCOME AFTER SURGERY AND RADIOTHERAPY FOR PETROCLIVAL MENINGIOMAS

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CERTIFICATE

Certified that the accompanying dissertation titled: **AN EVALUATION OF OUTCOME AFTER SURGERY AND RADIOTHERAPY FOR PETROCLIVAL MENINGIOMAS** is the bonafide work by **Dr. Iype Cherian**.

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INTRODUCTION

Considering their proximity to cranial nerves, the basilar artery, and the brainstem, petroclival meningiomas represent some of the most formidable challenges in skull base surgery. They may attain surprisingly large sizes with minimal symptoms; and with continued growth in this location, their natural history is one of ultimate progression to fatality. The optimal treatment for these intriguing tumours is still controversial. Before 1970, the risk of mortality from resection of petroclival meningiomas, which form about five percent of posterior fossa meningiomas[1], exceeded 50%[2]. Now, with advanced techniques of microsurgical resection the mortality rates vary from 0 -10 %[2-13].

A clinical finding, an early involvement of the cranial nerve V, forewarns the physician to the petroclival location[3]. With MRI scans available widely, earlier diagnosis should be the rule, with the attendant benefits in terms of easier surgery and reduced morbidity.

Petroclival meningiomas grow very slowly, and they may have a tendency to invade the brainstem, cranial nerves, and encase the basilar artery and its perforators[2].

It is extremely difficult to achieve a total excision of a petroclival meningioma, especially its dural attachment, dural tail, and the involved bone. Therefore, it is impractical to apply the Simpson grading system to assess the degree of resection of petroclival meningiomas. In many cases it is not

possible to excise these tumors without producing devastating deficits. Recent studies favour a subtotal excision when a total excision poses a high risk of unacceptable deficits. Residual tumour is probably best treated with focused radiation[9, 12]. Studies have demonstrated improved outcome and survival rates in patients who underwent subtotal resection plus radiation therapy[14-21] compared to surgery alone. In general, tumor control rates after subtotal resection and fractionated radiation therapy range from 72 to 95%, with variable lengths of follow-up[15,17,20,21].

We present our experience in treating these tumours in the last ten years at Christian Medical College, Vellore. Five surgeons were involved in this series over a period of 10 years. Therefore the degree of conservative /aggressive policies varied between surgeons and even between the same surgeon with time.

AIMS AND OBJECTIVES

1. To study the outcome after surgery and radiotherapy for petroclival meningiomas.
2. To compare the outcomes of aggressive and conservative surgery.

LITERATURE REVIEW

Petroclival meningiomas are rare tumours[1]; and they represent some of the most formidable challenges in skull base surgery. These lesions may attain surprisingly large size with minimal symptoms; however, with continued growth in this location, their natural history is one of ultimate progression to fatality.

Classification of Posterior fossa meningiomas :

Until about 10 years ago, meningiomas of the posterior fossa were classified by the criteria elaborated in 1953 by Castellano and Ruggiero[22]. This classification includes five groups: 1) cerebellar convexity; 2) tentorium; 3) posterior surface of the petrous bone; 4) clivus; and 5) foramen magnum. That grouping was accepted and used until the advent of the CT scan as a diagnostic aid and of the microscope as a surgical tool. By 1980, articles began to appear suggesting that the classification must be revised in order to regroup under a single heading such meningiomas of the basal posterior cranial fossa that could no longer be assigned to the clivus or to the pontocerebellar angle. Yasargil et al[23,] were the first to deny the existence of midline clivus meningiomas and recommended a subdivision of the basal posterior cranial fossa into clival, petroclival, and sphenopetroclival areas, the foramen magnum, and the cerebellopontine angle.

In 1984, Sekhar et al[5] stressed that "the site of dural attachment of these tumors often extends from one area into another"; in describing their respective series of cases. These tumours were referred to as "meningiomas of the clivus and apical petrous bone." by Mayberg and Symon[11], "petroclival and medial tentorial meningiomas," by Sekhar and Samii[24, 25], "petroclival meningiomas," by Al-Mefty et al[26] and Samii et al[25] **"**meningiomas involving the clivus and cerebellopontine angle," by Spetzler et al[8] and "petroclival - cavernous" meningiomas by Couldwell et al[10]. From such nomenclature emerges a group of meningiomas probably best labeled petroclival[3,7], to include the old clival meningiomas of earlier classifications and a subgroup of meningiomas of the cerebellopontine angle attached medial and anterior to the porus acousticus and trigeminal nerve. The group so defined is actually homogeneous in more ways than one. Thus, 1) in addition to the clivus area proper, the dural attachment may involve the petrous apex, the medial tentorium, Meckel's cave, the parasellar region, and the petrous and cavernous sinuses; 2) dural attachment often goes beyond the dura to affect the extradural space and bone and to infiltrate cranial nerves at their exit points; and 3) these tumors always develop medial to cranial nerves V, VII-VIII, and IX-XI and may encase the basilar artery and its branches as well as the internal carotid artery and circle of Willis. For all of these reasons, the group as a whole presents difficult surgical problems. In other words, these tumors are also homogeneous in terms of surgical challenge.

Natural history:

The natural history of meningiomas is characterised by slow but relentless growth resulting in compression of adjacent structures. Petroclival meningiomas are no exception to this rule. Cushing and Eisenhardt[27], described these tumours as relentlessly progressive with ultimately fatal outcomes**.** Studies by Bricolo et al[3] and recently Jung et al[9] provided indirect information on the natural history of these tumours after partial resection. The relentless evolution of these tumours is clearly reflected in the progressive involvement of cranial nerves.

Early on, the young meningioma growing on the petroclival line into the lateral clivus proceeds with the protection of the arachnoid from the superior cerebellopontine, prepontine, and ambient cistern, making surgical manipulation a good deal easier and safer. Later on, the tumor's base grows larger, digs through the dura, and invades the underlying bone, violating the arachnoid layers and implicating cranial nerves and arteries.

Growth Rate of petroclival meningiomas and factors influencing the growth rate:

To date very little is known about the growth rates of petroclival meningiomas. Jaaskelainen et al[28] reported the growth rates of intracranial meningiomas in general. They studied the growth rate of intracranial meningiomas in 43 patients against a histologic grading based on the degree of anaplasia. The mean time for doubling of the tumor volume was 415 days in grade I or benign, 178 days in grade II or atypical, and 205 days in grade III or

anaplastic. The difference between grade I and the combined grades II-III was highly significant. They found that the mitotic index and the absence of calcification on the computed tomography scan correlated strongly with the doubling time.

In a recent article, Jung et al[9] reported growth rate data for residual petroclival meningiomas after partial resection. They observed growth rates ranging from 0.37 to 4.94 cm^3/ year in volume with significant correlations between lower growth rates and old age as well as occurrence of menopause. However, Van Havenbergh et al[29] studied 21 patients with petroclival meningiomas who did not undergo surgery for a period of four years. The significant correlations between lower growth rates and old age and the occurrence of menopause reported by Jung et al[9]. were not confirmed by their data. They found the overall growth rates were 0.81 mm/yr in diameter and 0.81 cm^3/yr in volume when nongrowing tumor data were included in those calculations. When only growing tumors were considered, the mean growth rates were 1.16 mm/yr in diameter and 1.10 cm^3/yr in volume. These growth rates differ substantially from those reported by Jung et al. It could be concluded that remnants of partially surgically treated petroclival meningiomas grow faster, however it is likely that these studies were dealing with tumours of differing proliferative potentials.

The proliferative index also has been linked to the growth rate of these tumours[30, 31]. Matsuno et al[30] studied proliferative potentials of meningiomas from 127 patients immunohistochemically using the anti-Ki-67 monoclonal

antibody, MIB-1, on paraffin sections, and the correlation among MIB-1 staining index, histopathological finding, and clinical course of the disease. Higher MIB-1 staining index was observed for younger patients. The mean MIB-1 staining index in these patients was 1.6%, 3.6%, and 8.8%, respectively for non recurrent meningiomas, recurrent meningiomas at the time of initial surgery and at surgery for the recurrence. Statistical analyses revealed that meningiomas with a MIB-1 staining index of 3% or more have a significantly high tendency for recurrence during the clinical courses, especially within the first 10-year follow-up periods. Moreover, there was statistically significant correlation between MIB-1 staining index and recurrence in each Simpson's grade. They also observed that there was no statistically significant relationship between cellularity and MIB-1 staining index of meningiomas. Abramovich et al[32] also observed that there is a statistically significant difference in the increasing MIB-1 labelling index between benign, aggressive, and malignant meningiomas. From our institution, Devaprasath et al[34], studied 223 meningiomas, where a correlation for individual histological parameters like mitotic index, small cell formation, increased cellularity, sheet like architecture, necrosis, cellular atypia and brain invasion with MIB-1 labeling index was looked at. They found a good correlation of MIB-1 labeling index with mitotic index, small cell formation, sheet like architecture and increased cellularity and a poor correlation of MIB-1 index with necrosis, cellular atypia and brain invasion. Moreover, they concluded that, the MIB-1 labeling index has a high degree of validity at the level of 7 percent in the diagnosis of

histological atypia in meningiomas, and used in conjunction with the histological features, MIB- 1 labeling index can predict aggressive behaviour in meningiomas.

Diagnosis:

Currently, high-resolution computed tomography (CT) scanning, bone algorithms, Magnetic resonance imaging (MRI), and selective digital subtraction angiography, affords accurate diagnosis of these meningiomas, covering their size and location as well as the extent of tumor implantation on the skull base. With this information at hand, the surgeon can build a realistic mental image of the lesion and its relationships to neighboring nerves and blood vessels, thereby minimizing the risk of unforeseen difficulties. The surgeon will also be able to choose the surgical approach most suitable for the individual patient, although that choice will always depend largely on personal experience.

Unfortunately, these tumors are still being diagnosed too late, as shown by the long duration of reported symptoms, 35 months on average. To date, tumor size at the time of surgery emerges as the prime factor influencing the patient's final outcome[3,11]. It has to be stressed that, whenever surgeons detect impairment of any cranial nerve from 3rd nerve to 10th, however isolated, they should immediately request a CT scan and MRI brain. CN V is often the first to show signs in the early stage of tumor development[3], and it stands to reason that nowadays, with the MRI scan widely available, earlier diagnosis

should be the rule, with the attendant benefits in terms of easier surgery and reduced morbidity[3].

The common neurological findings associated with this tumour are cranial nerve involvement which varied from 37-67 %, ataxia 14-90 % and long tract involvement (3-12%) [3-7,9-10]

Microsurgical anatomy of the petroclival region:

Before discussing the surgical approaches in detail, the complex anatomy of the petroclival region taken from Rhotons text[33] will be discussed in brief.

Petroclival region:

The petroclival region is located where the posterior surface of the petrous temporal bone meets the clival part of the occipital bone along the petroclival fissure. The junction of the two bones forms a line that extends from the jugular foramen to the petrous apex. From a surgical standpoint, the intradural compartments of the petroclival region are divided along this petroclival line into 1) an inferior space related to the medulla and to the structures around the region of the foramen magnum; 2) a middle space related to the pons and to the structures in the prepontine and cerebellopontine angle; and 3) a superior space related to the contents of the interpeduncular cistern, and to the sellar and parasellar regions.

The inferior petroclival space:

The inferior petroclival space corresponds to the anterior surface of the medulla and adjacent part of the clivus and anterior margin of the foramen magnum. The neurovascular structures in this region are those contained in the premedullary cistern. The superior limit is the junction of the pons and medulla. The inferior limit is the rostral margin of the first cervical nerve root, the site of the junction of the spinal cord and the medulla. The inferior petroclival space includes the lower four cranial nerves, lower part of the cerebellum, the vertebral artery and its branches, and the structures around the occipital condyle.

The middle petroclival space:

The middle petroclival space corresponds to the anterolateral surface of the pons and cerebellum. Its superior limit is at the pontomesencephalic sulcus and the lower limit is at the pontomedullary sulcus. The lateral limits are formed by the posterior surface of the petrous bone and by the contents of the cerebellopontine angle including the trigeminal, abducens, facial, and vestibulocochlear nerves, the basilar artery, and the anterior inferior cerebellar artery and the superior petrosal veins.

The superior petroclival space:

The superior petroclival space is located anterior to the midbrain and corresponds to the anterior part of the tentorial incisura. It extends anteriorly and laterally to the sellar and parasellar regions. Its roof is formed by the diencephalic structures forming the floor of the third ventricle. The posterior

limit is formed by the cerebral peduncles and the posterior perforated substance. The inferior limit is situated above the origin of the trigeminal nerve at the pontomesencephalic sulcus. It includes the intradural segment of the oculomotor and trochlear nerves, the basilar artery and its branching into the posterior cerebral artery (PCA) and superior cerebellar artery (SCA), and the cavernous carotid and its intracavernous branches to the dura of the upper clivus. The medial edge of the tentorium divides the superior petroclival space into infra- and supratentorial compartments.

Concept of "Zones" in the petroclival region

Petroclival meningiomas are located in an anatomically demanding region replete with critical neurovascular structures. Despite a better understanding of the microsurgical anatomy and the great advances in standard operative technique, the surgical resection of petroclival meningiomas remains a substantial challenge. The transpetrosal corridors to the clival region are commonly used approaches, with the advantages of a short trajectory and minimal brain retraction. The clivus and petroclival area can be divided into three zones, based on anatomic findings and clinical experience with the transpetrosal approaches[4].

Zone I: represents the area from the dorsum sellae to the internal auditory canal and it is exposed via the anterior petrosal approach.

Zone II: represents the area of the petroclival region between the internal auditory canal and the upper border of the jugular tubercle. The lateral portion of Zone II is easily exposed via the posterior petrosal approach.

Zone III: represents the area between the upper border of the jugular tubercle to the foramen magnum. Lesions reaching or affecting Zone III are considered to be in the foramen magnum. Zone III of the clivus and the petroclival region is exposed via the lateral suboccipital/transcondylar approach.

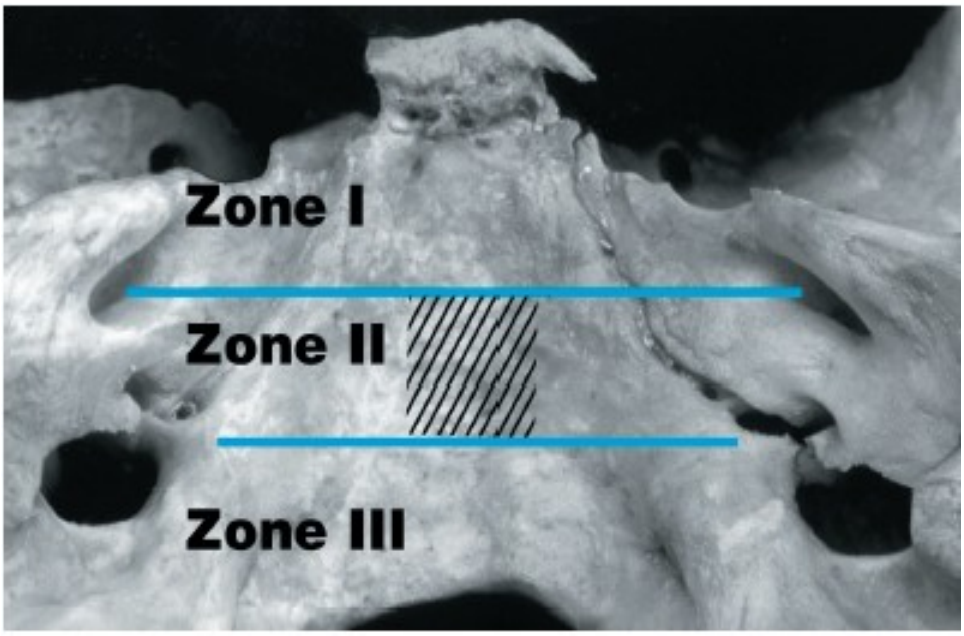

Figure 2: Photograph of a dry human skull showing the three clival zones separated by blue lines. Zone I (upper zone) extends from the dorsum sellae to the upper border of the internal auditory canal. Zone II (middle zone) extends from the upper border of the internal auditory canal to the upper border of the jugular tubercle. The central clival depression is shown by the hatched area. Zone III (lower zone) extends from the upper border of the jugular tubercle to the lower edge of the clivus. (acknowledgement- photograph copied from the article Abdel Aziz KM, Sanan A, van Loveren HR, Tew JM Jr, Keller JT, Pensak ML. Petroclival meningiomas: predictive parameters for transpetrosal approaches. Neurosurgery. Jul;47(1):139-50, 2000[4]).

The paramedian portion of Zone II, or the central clival depression, cannot be exposed via the posterior petrosal approach because the remaining temporal bone poses an immovable obstacle around which the surgeon cannot adequately see. Therefore, tumors with dural attachment in the central clival depression cannot be totally resected with the posterior petrosal approach. It is noteworthy that some meningiomas occupying the central clival depression, without attachment, do roll out easily. A distinction should be made between merely occupying the space of the central clival depression, which is a favorable situation, and being attached to the dura of the central clival depression, which is an unfavorable situation.

The greater the depth of the central clival depression from the intermeatal plane, the more likely that the tumor is potentially left in a relatively inaccessible region. Exposure of the central clival depression necessitates the posterior petrosal translabyrinthine / transcochlear approach with posterior mobilization of the facial nerve.

MODALITIES OF TREATMENT:

Surgery:

Petroclival meningiomas usually extend into more than one zone necessitating two or three approaches. It is extremely difficult to achieve total excision of a petroclival meningioma, including excision of its dural attachment, dural tail, and the involved bone. The traditional paradigm for convexity meningiomas requires the neurosurgeon to achieve a total resection, and this is very appropriate, since aggressive removal is not

associated with increased morbidity and can reduce the recurrence rate[36]. As the meningioma becomes more basal, the surgical morbidity for attempted total resection increases dramatically. Furthermore, despite major attempts to perform a total removal of tumor, there are microscopic nests of cells on the involved basal dura, a dural surface that cannot be excised[4]. Ultimately, for meningiomas attached to the dura in Zone II, the surgical morbidity associated with total removal becomes prohibitive, and in many cases it is not possible to excise tumors without producing devastating deficits[4].

Surgical approaches:

The approaches for petroclival menigiomas has changed over the years from the classical three routes, namely the retromastoid, the subtemporal, and the combined supratentorial and subtentorial presigmoid transpetrosal routes to complex approaches involving anterior petrosectomy, posterior petrosectomy or both.

a). The retromastoid route:

The classical retromastoid approach, with unroofing of the transverse and sigmoid sinuses to keep them out of the surgical field and moderate, readily tolerated, cerebellar retraction, affords the simplest access to the region of the cerebellopontine angle. The surgeon must conduct the whole phase of removal through the fissures made by the tentorium and by cranial nerves V, VII-VIII, and IX-XI, all of which may be contused in the process. Supratentorial, subtemporal, and parasellar tumor expansion do not alone disqualify or contraindicate this simple and thoroughly tested approach, which

has rewarded many surgeons with excellent results. Access to the area is prepared by the tumor itself, located in the tentorial hiatus, and it can be amplified by resection of the tentorial flap. Thus, even the upper pole of the tumor, if not attached to the parasellar dura, can be dislocated downward and removed by being separated from the arachnoid of the interpeduncular and chiasmatic cisterns. Conventional posterior cranial fossa surgery can be suitable for a select group of petroclival meningioma. Goel et al[38] in his series of petroclival meningiomas operated through this route mentions that this approach provides easy and quick exposure of the tumor without any petrous bone drilling. It also provides a direct and early exposure of the tumor-cranial nerve-brainstem interface facilitating the dissection. The lateral and inferior tumor extensions in relationship to the clivus can be more easily accessed. The site of attachment of the tumor to the dura overlying the posterior face of the petrous apex can be seen directly**.** However, the surgeon needs to operate between the cranial nerves 5th to 9th which will be stretched over or encased by the posterior capsule of the tumour.

b). Middle fossa approaches:

Approaches through the middle fossa[39-43,] afford immediate visibility and complete control of the supratentorial tumor bulge. However, it is also a highly hazardous route. Both the pterional and, even more so, the posterior subtemporal approaches actually afford excellent exposure of the parasellar area and tentorial notch. Yet, retraction of the temporal lobe, however limited, causes some postoperative morbidity, especially on the dominant side.

Access to the posterior fossa also remains narrow and tedious, affording insufficient command of cranial nerves below V. The combined posterior subtemporal and presigmoid transpetrous approach without sinus division embodies some important refinements[7] of the original approach described by Hakuba[39]. Via radical mastoidectomy, the sigmoid sinus is exposed down to the jugular bulb, and via the transmastoideal-subtemporal approach the retroauricular petrosal bone, 1 cm in depth from the petrosal ridge, and the roof of the internal auditory meatus are removed, the middle ear and fallopian canal being left intact. Additionally, via a transzygomatic-subtemporal approach, the preauricular petrosal bone is removed anteriorly up to the petrosal tip and laterally as far as the petrosal portion of the internal carotid artery, while the cochlea is preserved. By this means, the triangular portion of the posterior petrosal dura mater, delimited by the superior petrosal sinus, inferior petrosal sinus, and sigmoid sinus, is well exposed extradurally. By opening the subtemporal and posterior petrosal dura mater, in combination with a tentoriotomy, adequate exposure of the basilar artery, vertebral arteries, ventral and lateral portions of the brainstem, and cranial nerves is achieved with minimal retraction of the temporal lobe and cerebellum.

This approach by Hakuba[39] and his associates turns out to be the more elegant and less dangerous way to reach petroclival meningiomas that involve a large portion of the skull base from the lower clivus to the parasellar area. The access afforded by the retromastoid or subtemporal route is too restricted unless one is willing to face a two-stage operation. The approach of

Hakuba et al[39]. allows the surgeon to work about 2 cm closer to the tumor than would be possible through the retrosigmoid approach and in front of the brain stem Division of the tentorium materially reduces the need for retracting the cerebellum and temporal lobe, preserves drainage of the vein of Labbé, and creates an excellent exposure, opening an unimpeded vista from the lowest cranial nerves to the sella. In particular, it affords control of the whole intracranial course of cranial nerves III and IV with less risk of injuring those structures. The trunk of the basilar artery and its terminal branches are eventually well exposed, as are the contralateral V and III cranial nerves and the pituitary stalk. The approach requires good knowledge of periotic bone anatomy to spare the labyrinth and facial nerve. It also requires a good deal of patience and meticulousness because, like the retromastoid, this approach forces one to work lateral to cranial nerves V-XI as well as between them.

c). Combined supra- and infratentorial presigmoid approach:

In this approach, the skin incision is started in the temporal region above the zygoma, and extends above the ear and downward in the suboccipital area medial to the mastoid process. The skin flap is reflected forward to the level of the external auditory canal. The temporal muscle is elevated and reflected anteriorly, and the muscles over the mastoid and suboccipital areas are swept inferiorly. A temporo-occipital craniotomy is performed and the transverse sinus is exposed. After the bone flap is elevated, a mastoidectomy is carried out without entering the labyrinth. The sigmoid sinus is skeletonized from the sinodural angle to the jugular bulb.

Bone is removed superiorly to expose the floor of the middle fossa and the superior petrosal sinus. Trautman's triangle is exposed in the area lateral to the otic capsule. The dura mater is then incised along the base of the temporal craniotomy, while preserving the junction of the vein of Labbe´ with the transverse sinus. The posterior fossa dura is opened anterior to the sigmoid sinus in Trautman's triangle. The dural incision is extended across the superior petrosal sinus to join the dural incision in the temporal dura. After division of the superior petrosal sinus, the tentorium is incised parallel to and just behind the petrous ridge and superior petrosal sinus. This dural incision is extended from the site of division of the superior petrosal sinus through the medial edge of the tentorium to the incisura behind where the trochlear nerve enters the tentorial edge. Care is taken to avoid injury to the IVth cranial nerve in its course near the tentorial margin. The posterior portion of the temporal lobe is elevated and the sigmoid sinus is displaced posteriorly along with the cerebellar hemisphere while preserving the junction of the vein of Labbe´ with the sigmoid sinus. The sigmoid sinus limits the ability for superior retraction of the temporal lobe and can be ligated to improve the exposure if bilateral venous angiography shows adequate communication through the torcular to the opposite side. The petroclival region can be exposed from the middle fossa and tentorial incisura to near the foramen magnum, although access to the lower petroclival region may be limited by the jugular bulb. The presigmoid exposure provides a shorter working distance to the petroclival area and provides multiple angles for dissection. The major arteries in the posterior

fossa are easily accessible. The exposure can also be combined with a far-lateral approach.

d). Petrosal approaches:

These approaches have been shown to offer distinct advantages over traditional operations in approaching lesions of the petroclival area[4,6,39].

Confusion about these approaches exists due to the variety of names given to these procedures and the lack of detailed descriptions needed to perform them. After extensive review of the literature, Miller et al [41] have determined that all transpetrosal techniques fall into one of two categories: anterior petrosectomy or posterior petrosectomy. Combining one of these procedures with existing conventional procedures accurately describes all existing transpetrosal operations and eliminates confusion over nomenclature. In addition, through a series of cadaveric dissections and operative experience, they have detailed each of these procedures as a series of steps that will enable the surgeon to understand the unfamiliar anatomy of the temporal bone and to perform these transpetrosal techniques.

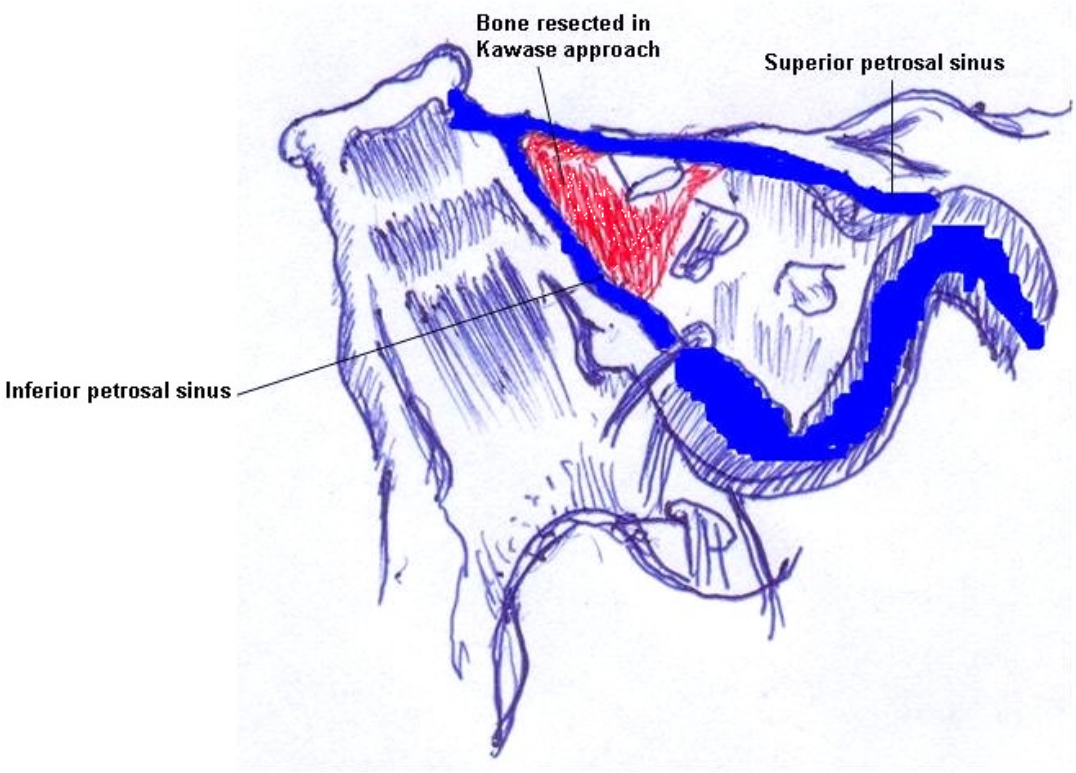

Figure 2: Shows the petroclival region. The amount of bone resected in Kawase's approach shown in red. (Modified from Abdel Aziz KM, Sanan A, van Loveren HR, Tew JM Jr, Keller JT, Pensak ML. Petroclival meningiomas: predictive parameters for transpetrosal approaches. Neurosurgery 2000[4]Jul;47(1):139-50)

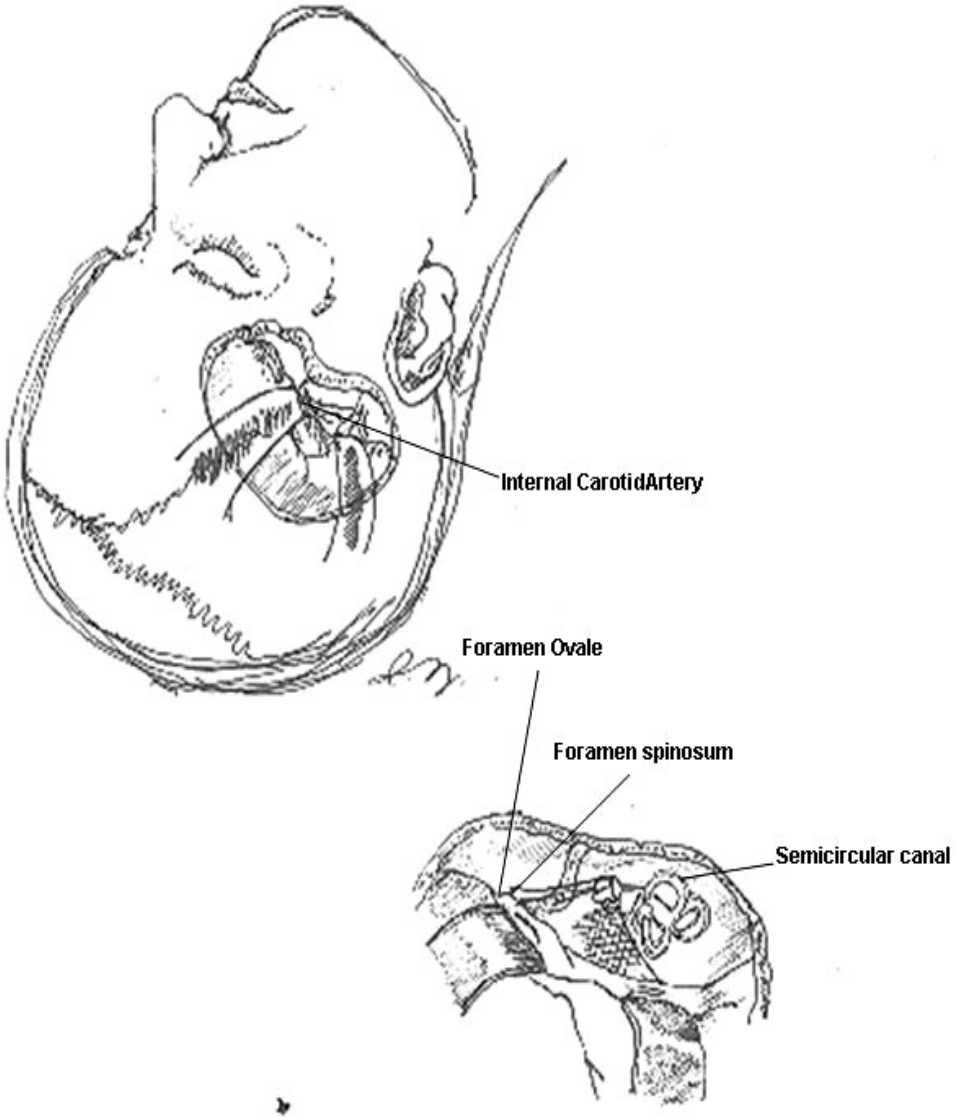

Figure 3: Shows subtemporal craniotomy and the extradural exposure in Kawase's approach (Modified from Abdel Aziz KM, Sanan A, van Loveren HR, Tew JM Jr, Keller JT, Pensak ML. Petroclival meningiomas: predictive parameters for transpetrosal approaches. Neurosurgery 2000[4]Jul;47(1):139-50)

Anterior petrosectomy:

This approach was originally described by Kawase[40]. Here the anatomic boundaries of the Kawase and Glasscock triangles[41] are identified initially after subtemporal extradural approach. The boundaries of Glasscock's triangle are laterally, a line from the foramen spinosum to the facial hiatus; medially, the greater superficial petrosal nerve; and at the base, V3. The boundaries of Kawase's triangle are laterally, the greater superficial petrosal nerve; medially, the petrous ridge; and at the base, the arcuate eminence. The ICA is exposed in Glasscock's triangle. The posterior fossa dura is exposed down to the level of the inferior petrosal sinus by resection of the bone of Kawase's triangle.

A section of inferior temporal lobe dura, elevation of temporal lobe, sacrifice of superior petrosal sinus, section of tentorium cerebelli, and opening of posterior fossa dura is done in a sequential manner. This approach has been modified by others over time[4].

Posterior petrosectomy:

The posterior petrosal approach consists of a temporal craniotomy combined with a presigmoid craniectomy. Depending on the preoperative hearing status and the need for additional exposure, either a retrolabyrinthine or a translabyrinthine bony exposure is chosen. The dural opening is made as follows: 1) dura is incised along the undersurface of the temporal lobe parallel to the superior petrosal sinus, taking care to preserve the vein of Labbe´, which generally enters the transverse sinus within 1 cm of the transverse-sigmoid junction; 2) the posterior fossa dura in the presigmoid space is incised

longitudinally between the superior petrosal sinus and the jugular bulb; 3) with gentle traction on the temporal lobe and cerebellum, the superior petrosal sinus is sectioned between two titanium clips; 4) the tentorium is sectioned into the incisura at a point posterior to its junction with the trochlear nerve; and 5) an incision that relaxes the dura is made along the upper border of the transverse sinus. This allows for a generous exposure between the trigeminal nerve and the upper border of the jugular tubercle. If additional exposure is required caudal to the jugular tubercle, a retrosigmoid craniectomy with or without partial condylar resection (transcondylar approach) is performed.

Radiosurgery :

The considerable postoperative morbidity and mortality rates, even in very experienced hands, have led to the use of stereotactic radiosurgery for these tumours. Obviously, the objective differs essentially from that of surgery, because the goal is prevention of tumour progression instead of cytoreduction. Subach et al[37].reported on a series of 62 patients who were treated with stereotactic radiosurgery (as a primary treatment in 23 cases). With a follow up period of 38 months there was 100 percent tumour control. Iwai et al reported[51] 11 cases of petroclival meningiomas treated with radiousurgery with 100 percent tumor control during a period of 30 months. Nicolata et al[52] presented a series of 62 posterior fossa meningiomas (23 petroclival meningiomas) that were treated with Gamma knife surgery. The treatment was used as primary therapy, as well as adjuvant therapy for recurrent or residual tumours after surgery. With a follow up period of 29 months, those authors

observed tumor or mass reduction in 95 percent cases; there was tumor progression in 5 percent of cases. For this total of 13 patients treated with stereotactic radiosurgery, there was a morbidity rate of 5.9 percent. The main disadvantages remain the relatively short follow up and the possible negative effects of radiosurgery on tumour biological process.

Stereotactic radiosurgery provides a conformal, highly focused, single fraction radiation field essentially confined to the tumor, which may reduce the incidence of complications that are occasionally associated with fractionated radiation therapy[47-48]. Multiple isocenter dose planning, using small beam diameters facilitates precise delineation of the radiation dose to the often irregular margins of the tumor. The steep radiation fall-off of radiosurgery significantly protects adjacent critical structures from delayed radiation-induced injury. This benefit is eventually limited, however, as tumor volumes increase. Unfortunately, the indolent nature of petroclival meningiomas generally brings them to clinical attention only after significant growth has occurred. In general, tumors larger than 25 to 30 mm in average diameter are associated with significant local brain compression that may require initial surgical resection[46]. The risk of complications after radiosurgery is considerably lower than those risks reported after microsurgery[49-50]. It is possible that younger patients present with more aggressive tumors that require initial surgical intervention; such patients may also have a higher risk of recurrence. In contrast, older patients may be less suitable candidates for resection because of age related medical risks[37]. Longer follow-up is clearly

necessary to define long-term tumor control rates. Fractionated radiation therapy, which may improve both outcome and survival rates after subtotal resection, has a higher risk of radiation induced complications than does radiosurgery. With the use of relocatable stereotactic guidance, the safety of fractionated radiation therapy may be enhanced. For patients with malignant meningiomas, fractionated radiation therapy remains the primary treatment and should be initiated early after resection[37]. Stereotactic radiosurgery may be of benefit to patients with malignant meningiomas as a "boost" technique to a previously radiated tumor[37]. To maximize the potential benefits of stereotactic radiosurgery and microsurgery, Kondziolka et al[48] proposed a treatment algorithm

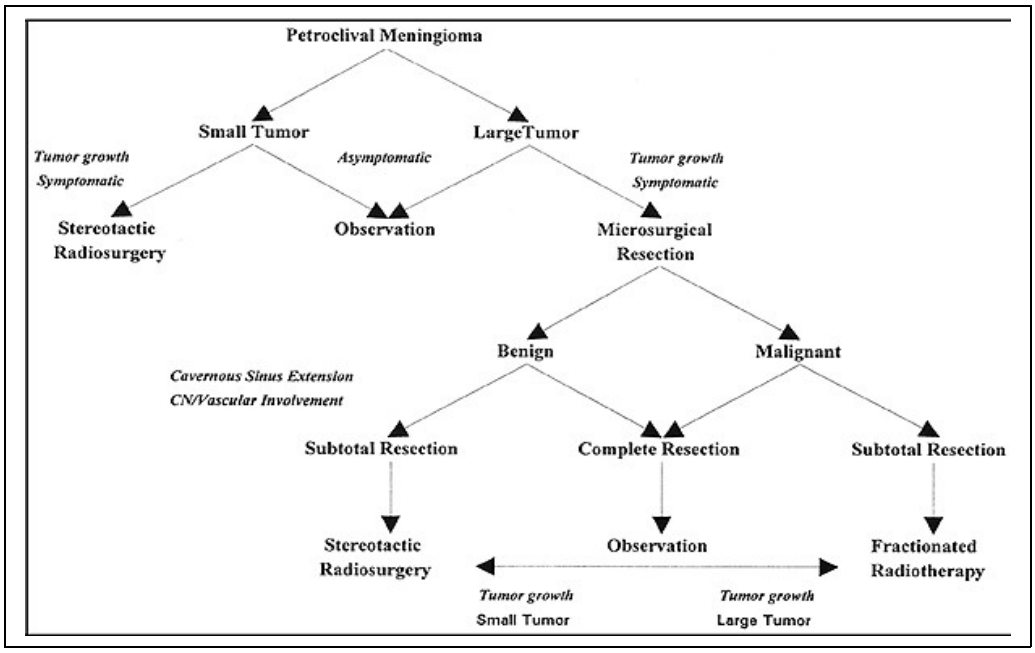

Figure 4 – Treatment algorithm for petroclival meningiomas as proposed by Kondziolka et al [48] for the management of petroclival meningiomas.

Regardless of tumor size, treatment should be reserved for patients with related symptoms. Based on the indolent nature of some petroclival meningiomas, serial neurodiagnostic imaging is indicated for asymptomatic or incidentally discovered tumors. Once symptoms develop or growth is documented, appropriate management should be initiated based on tumor size. For patients with tumors smaller than or equal to 30 mm in average diameter, they think that stereotactic radiosurgery is the best primary treatment. In their experience, all patients managed with this strategy had subsequent tumor control and low accompanying morbidity. For patients with larger tumors (e.g., average diameter > 30 mm), surgical resection should be considered. Although the goal of surgery should be complete resection, this must be tempered by the need to prevent serious postoperative neurological injury. For patients with tumors engulfing critical vascular structures or invading the cavernous sinus, a strategy of subtotal resection plus radiosurgery should be used. Patients with atypical or malignant meningiomas should receive fractionated radiation therapy plus "boost" radiosurgery. Individual patient characteristics, such as age, functional status, and general medical condition, also influence the decision-making process.

Subtotal Surgery with Radiation

Complete curative resection of petroclival meningiomas is frequently impossible. The likelihood of complete resection varies between 26 and 79%, even when recently published reports are included[3,5-11,25]. Most recent additions to the literature, however, also describe significant morbidity associated with surgical intervention. From 2 to 10% of patients die as a direct result of surgery. The risk of hemiparesis varies from 7 to 45%, and persistent coma has been reported in 12 to 27% of surgical patients. Permanent cranial nerve deficits resulting from surgery were noted in 22 to 91% of patients. On average, 54% of patients will develop new neurological deficits as a result of surgery[3,5-11,25]. Some surgeons have opted for a less aggressive approach to resection, such as tumor debulking or subtotal resection, to reduce morbidity associated with the procedure. Unfortunately, incomplete resection alone fails to affect tumor progression rates[44]. In a retrospective review of 53 meningioma patients, Marks et al[45] observed that the rate of tumor recurrence after complete resection was 9.5% at 5 years, in contrast with a 20% recurrence rate after subtotal resection. Similarly, Kallio et al[46] studied 225 patients with meningiomas after complete resection and found recurrence rates of 7, 20, and 32% at 5, 10, and 15 years, respectively, after surgery. In contrast, the rates for tumor progression after subtotal resection were 37, 55, and 91%, respectively, for the same time intervals. These relatively high rates of tumor progression and recurrence support the addition of a secondary treatment modality for better tumor control. The role of external beam fractionated radiation in the management of meningiomas has generally been limited to

postoperative adjunctive treatment. Recent studies have demonstrated improved outcome and survival rates in patients who underwent subtotal resection plus radiation therapy[14-21,]. These studies have determined a 10-year progression-free survival rate of 18% after subtotal resection alone, 77% after gross total resection, and 82% after subtotal resection plus radiation therapy. In general, tumor control rates after subtotal resection and fractionated radiation therapy range from 72 to 95%, with variable lengths of follow-up[14-17,19-21]. However, despite the apparent improvement in tumor control rates, approximately one-third of patients experienced related complications. Al Mefty et al[26] evaluated 58 patients an average of 8.1 years after radiation therapy. Twenty-two patients (38%) developed major complications, such as visual loss, pituitary dysfunction, and brain radiation necrosis. Miralbell et al[15] reported that 6 of 36 patients (17%) developed radiation-related complications during an 88-month follow-up period.

"The optimal treatment":

The ideal treatment for these tumours is continuously under discussion, because of their low incidence, their variable biological behavior and their specific location near the brainstem and cranial nerves which makes surgery hazardous, even with the latest techniques and approaches.

It is clear that complete resection is theoretically the optimal treatment, especially if surgery could be performed with negligible morbidity and no risk of death[7]. Hakuba et al[39] presented a series of six patients who underwent a total tumour removal with an operative mortality rate of 17%[23]. Sekhar et al[24]

reported total resection in 35% cases with a mortality rate of 15%. The same authors observed that cranial nerve palsy, prior treatment and radiological features (tumor size, vessel encasement and multiple fossae involvement) were significant factors influencing postoperative outcomes[24].

Park et al[12], after dividing a population of petroclival meningiomas into microsurgery group, radiosurgery group, radiation group and radiosurgery group made observations that the incidence of favorable outcomes for cranial neuropathies was better in the incomplete resection group (69.2%) than for patients in the complete resection group (20%, p value = .032). Also, favorable functional outcome predominated in the incomplete resection group (76.9%) compared with the complete resection group (30%, p value = .049). The disease was stable in both the radiation therapy and the radiosurgery groups during the follow-up period, with functional status and cranial nerve function perfectly preserved in these patients. They concluded that intended incomplete resection should be considered as an acceptable treatment option and that adjuvant treatment after surgery is useful in the control of residual tumors.

The present data on the natural history of petroclival meningiomas suggest that most of these tumours are growing incessantly. Small and medium size tumours seem especially prone to more growth. Therefore active treatment for symptomatic patients with small or medium sized tumors is mandatory. For younger patients, surgery is the treatment of choice; for elderly patients or patients who cannot undergo surgery, stereotactic radiosurgery should be proposed[29]. It is also noticed that, for 50 percent of the growing

tumours, a clear change in the growth rate preceded clinical deterioration. On the basis of these findings, observation (with meticulous radiological follow up monitoring) could be considered for asymptomatic patients with small petroclival meningiomas. An increase in growth rate should lead to active treatment without delay. For large symptomatic tumours, the treatment should be safe microsurgical resection, especially of the infratentorial part, followed by stereotactic radiosurgery as an adjuvant treatment, if possible[51].

MATERIALS AND METHODS

This was a retrospective review of petroclival meningiomas operated from 1995-2004. Petroclival meningiomas were defined as tumours, where the primary attachment was anteromedial to the internal auditory meatus.

There were 122 cases, of meningiomas with a petrous attachment. However, since our primary interest was in petroclival meningiomas, 81 petrous meningiomas with dural attachment posterior to the internal auditory meatus were excluded leaving 41 petroclival meningiomas. Petroclival meningiomas that were operated elsewhere, but came here for other modalities of treatment like SRT, SRS were excluded.

Neuroradiological Evaluation:

All patients had preoperative and postoperative CT scans with contrast. All tumors carried the preoperative radiological diagnosis of meningioma amongst the differential diagnoses and were significantly contrast enhancing.

Preoperative protocol:

Regardless of the approach chosen, patients received dexamethasone 4 mg every six hours starting the day prior to surgery. Neurophysiological monitoring for cranial nerves 7, 8, lower cranial nerves (9,10^{th}) and brainstem was used for patients operated after the year 1992.

Approach Selection:

The cases have been operated by five surgeons. Our surgical approaches to the tumors included retromastoid, frontotemporal, combined supra and infratentorial presigmoid, middle fossa approaches and combined petrosal (anterior and posterior transpetrosal) approach. Surgical approach was predicted on the location of the epicenter of the tumor, direction of tumor extension, tumor size, patient age, medical comorbidities, and the surgeons comfort levels with various approaches.

The extent of resection (EOR) was decided by the intraoperative impression and the postoperative scans. Note that, some scans were not stored into the archive system and hence was not available for the verification, and data was obtained from the in-patient charts or discharge summary. Radical resection was defined as no tumour being left behind in the surgeon's impression and with little or no enhancing component seen in the postoperative scan. About 90 percent of tumour resected was termed subtotal and less than 90 percent resection was termed partial. For purpose of statistical analysis, we divided the patients into two groups i.e., the radically excised and the subtotally excised were grouped into one while the partially excised and biopsied patients formed the second group. This way, the outcome of patients who underwent aggressive surgery could be compared to those patients who underwent conservative mode of surgery.

Patients who underwent radical excision did not undergo radiotherapy, but were advised to follow up on a yearly basis with serial imaging. Patients who underwent a subtotal excision were asked to undergo radiation therapy, at times immediately after surgery, and at times, they were asked to review after three to six months for RT/SRT. All patients who underwent biopsy or partial excision were asked to undergo radiation therapy. Options of stereotactic radiation and conventional radiation were given, and depending on financial status, patients chose between the two. One patient underwent stereotactic radiosurgery since stereotactic radiation was not available at this point of time and the residual tumour was less than 4 cm.

The primary outcome variables assessed were 1. Extent of resection (EOR), 2. Postoperative neurological deficits, both at immediate postoperative period and assessed at last follow-up, 3. Radiographic tumor recurrence or progression based on the last available radiographic evaluation and 4. Quality of life as assessed at the last follow up (if available in outpatient charts) or as a response to the questionnaire (whether dependent or independent for activities of daily life like taking food, taking bath and bowel bladder functions), that we had sent to the patients. New deficits which developed after surgery or those exacerbated beyond the preoperative baseline were combined for analysis of morbidity. Surgery related complications were also accounted into morbidity in the immediate postoperative period. Transient and minor deficits which improved, or were improving were excluded. Patients who were

discharged with Glasgow coma score of 13/15 or less, were included in the poor outcome group.

To obtain follow-up data, outpatient charts containing details of latest follow up, or a written questionnaire was used to assess the functional status.

Statistical analysis:

We used the SPSS -11 software (SPSS. Inc, Chicago, USA) and STATA - 8.0 software (STATA corporation, Texas, USA)) for statistical analysis. To compare the outcomes of the aggressive and conservative surgery groups, we first performed a chisquare test using the preoperative variables such as age gender, tumour size and clinical presentation to ascertain whether these two groups were comparable. Subsequently the outcome variables were compared between the groups using the odds ratio and p value. A p value of less than 0.05 was regarded as statistically significant.

RESULTS

There were 41 cases of petroclival meningiomas, with a mean age of 44 years (range 25-63, Standard deviation - 9.1). There were 31 females and 10 males. Table 1 shows a comparison of age, gender and preoperative deficits with respect to tumour size in these patients. It is seen that, tumours more than 4 cm size were found more commonly in patients less than 50 years of age (73%) with marginal statistical significance (p value = 0.06). Although the female gender had more incidence of petroclival meningiomas (75%), the tumour size distribution among the male and female gender was not statistically significant (p value = 0.6).

Presenting symptoms and signs: (also see table 1)

Presenting symptoms were related to cranial nerve impairment, cerebellar dysfunction, brainstem compression and increased intracranial pressure. The most common presenting symptoms in our series were imbalance of gait affecting 27/41 patients (65.8%) or headache 25/41(61%), whereas cranial nerve palsies represented the most common presenting signs, 39/41 (95%). Cranial nerves 3, 4 and 6 were involved in 7/41 patients (17%), the trigeminal nerve was involved in 29/41 (70.7%) and the facial nerve in 33/41 patients (80.5%), cranial nerve 8 in 22/41 patients (48.8%) and lower cranial nerve involvement (9^{th}, 10th) not requiring nasogastric feeds was seen in 13/41 patients (31.7%). Twenty-one patients (51.2%) had evidence of long tract signs in the form of hemiparesis with exaggerated reflexes or

hemisensory loss. Twenty five of the 41 (61%) patients had evidence of raised intracranial pressure as evidenced by papilledema. Thirteen of the 41 (32%) patients were dependent for activities of daily life, such as ambulation, feeding and for bowel/ bladder functions.

The deficits were analyzed on the basis of tumour size (Table 1). The incidence of cranial nerve deficits was 30/39 (77%) in patients with tumours more than 4 cm, while it was 9/39 (23%) in the patients with tumours less than 4 cm. Long tract signs were 13/21 (62%) in the group with tumours more than 4 cm while it was 8/21 (38.1%) in those with tumours less than 4 cm. The incidence of ataxia was 18/27 (66%) in the group with more than 4 cm tumours while it was 9/27 (33.3%) in the group of patients with tumours less than 4 cm. Raised intracranial pressure was seen in 18/25 (72%) in the group with tumours more than 4 cm while it was seen in 7/25 (28%) in patients with tumours less than 4 cm. Although the incidence of deficits were found to be higher in the group with the tumour size more than 4 cm, this was not statistically significant (p value= 0.67).

Radiology:

Seventeen patients had preoperative MRI scans while 24 patients had preoperative CT scans. Table 2 shows that the tumour size was 2-4 cm in 10 (24.4%) and more than 4 cm (75.6%) in 31 patients. No tumour was less than 2 cm in diameter. Twenty tumours were located on the right side and 21 were on the left side. Eleven patients had evidence of hydrocephalus. Of these, nine underwent a ventriculoperitoneal shunt, six in the preoperative period and

three in the postoperative period. On the MRI, 14 patients had evidence of vessel encasement with either the posterior cerebral or the basilar artery encased. Four patients had evidence of T2W hyperintensities in the brainstem. Six patients had extension of the tumour into the middle fossa with involvement of the cavernous sinus.

Surgery :

Table 2 shows the surgical approaches and extent of resection subclassified by tumour size. We used the retrosigmoid approach in 13 patients, the combined supra and infratentorial presigmoid approach in 18 patients; of which 10 were staged. The frontotemporal craniotomy with orbitozygomatic osteotomy was used in 9 patients for tumours with a large cavernous component, of which one was staged. The combined anterior and posterior transpetrosal approach was used for 1 patient.

Tumours in the 2-4 cm range, were operated using the retromastoid (6/10) and the combined supra and infratentorial presigmoid approach (4/10). Between 1995-2000, of the 24 petroclival meningiomas, 9 patients (37.5%) underwent a retromastoid approach while beween 2001 to 2005, 4 cases out of 17 (23.5%) were done through this approach. (Refer to data sheet in appendix).

Overall, 5/41 (12.2%) patients underwent a radical excision of their tumours while 17/41 (41.5%) patients underwent subtotal excision, 17/41(41.5%) patients underwent partial excision and 2/41 (4.8%) underwent biopsy of their tumours.

Complications: (also see table 3)

The surgery related complications included brainstem dysfunction, worsening of pre-existing cranial nerve deficits, wound leaks / CSF leaks, cerebellar infarcts and temporal hematomas. In the immediate postoperative period, 24 of the 41 (58.5%) patients had morbidity. 14 of the 41 (34.14%) patients developed cranial nerve deficits, four patients developed brainstem dysfunction, and two patients had temporal lobe hemorrhagic infarcts/hematomas. Another two patients developed cerebellar hemorrhagic infarcts/ hematomas of which one had brainstem dysfunction. Four patients developed CSF wound leaks and another two developed CSF otorrhea.

CSF leak/ CSF otorrhea:

Six patients had either CSF wound leak or CSF otorrhea. Four patients had CSF leak from the wound after suture removal. This was managed successfully with resuturing and lumbar subarachnoid drain for 5 days. One of them developed meningitis that required 2 weeks of antibiotics. Two patients developed CSF otorrhea, a week after surgery following the combined supra and infratentorial presigmoid approach despite waxing of the exposed bone and dural closure with pedicled temporalis fascia. One developed meningitis, and was managed with antibiotics. Cultures grew nonfermenting gram negative bacilli sensitive to cotrimoxazole. Both patients were managed with a lumbar subarachnoid drain for one week, bedrest and antibiotics for 2 weeks with which the rhinorrhea resolved.

Cranial nerve deficits:

It must be noted that the patients who had brainstem dysfunction also had worsening of multiple cranial nerves, hemiparesis and worsening of ataxia and their separate deficits are not included in these sections. In the immediate postoperative period 14/41 patients had developed new cranial nerve deficits. Five of these 14 also had worsening of their preexisting cranial nerve deficits. However, in 11/14 patients the deficits were transient deficits lasting for less than two weeks. These transient deficits included transient worsening of facial and trigeminal nerves. Thus, 3 patients had permanent deficits, one (4.5%) in the aggressive group who had worsening of 3,4,5,6 cranial nerves, and two (10.5%) in the conservative group who had worsening of 9^{th} 10^{th} cranial nerves, necessitating Ryles tube feeds in one patient for more than a month and a feeding gastrostomy in the other.

Temporal lobe hematoma/ hemorrhagic infarct:

There were 2 patients who developed temporal lobe hematomas in the immediate postoperative period. Both were from the aggressive resection group. One patient (case no: 32 – refer data sheet) underwent a combined supra and infratentorial presigmoid approach and subtotal excision of a left sided petroclival meningioma. At surgery, while the tentorium was cut and the temporal lobe retracted, a vein draining to the superior petrosal sinus was cauterized and cut. The duration of surgery was 12 hours. A postoperative scan was done the next morning since her sensorium remained at a Glasgow coma score of 12/15. This showed a hemorrhagic infarct in the left temporal

lobe with significant mass effect, possibly due to a vein of Labbe infarct, and with evidence of blood in the left cerebellopontine angle. There was no hydrocephalus. She was taken up for emergency re-exploration at which time, the temporal lobe and the cerebellum were tense due to a clot in the temporal lobe. The brain was lax after the surgery. She recovered to a Glasgow coma score of 13/15 and remained so till discharge.

The other patient (case: 14 - refer data sheet) also underwent a combined supra and infratentorial presigmoid approach and a subtotal excision of the tumour. Postoperatively, he continued to have a Glasgow coma score of 9/15 for 12 hours, therefore a CT scan was done that showed a 2 x 2 cm right temporal lobe hematoma. Since the hematoma was not exerting significant mass effect, he was managed conservatively; however his GCS did not improve and he remained to have a score of 9/15 at discharge.

Cerebellar hematoma/ hemorrhagic infarct :

There were 2 patients from the conservative group who developed cerebellar hematomas, both operated via the retrosigmoid route. One patient (case no: 8-refer data sheet) will be discussed later in the brainstem dysfunction group. The other patient (case no: 10 refer data sheet) underwent a partial excision of her right petroclival meningioma. At surgery, the tumour was internally decompressed. This patient had a Glasgow coma score of 13/15 on the first postoperative day and a CT scan showed a right cerebellar hemorrhagic infarct with dilated ventricles. An external ventricular drain was inserted before emergency evacuation of the hematoma. She made a good

recovery, was discharged with a Glasgow coma score of 15/15, underwent radiation therapy and was stable at 20 months follow up.

Brainstem dysfunction:

There were 4 patients who developed brainstem dysfunction. Three had tumours larger than 4 cm and underwent radical or subtotal excision of their tumours. One patient (Case 8 – refer data sheet) whose tumour size was 3.5 cm and who had conservative surgery developed a cerebellar and brainstem infarct in the immediate postoperative period. This patient underwent a left retromastoid suboccipital craniectomy and partial excision of the tumour in the sitting position. Tumour was left behind near the brainstem and hemostasis was achieved without any difficulty. She was extubated in the operation theatre and transferred to the intensive care unit with a Glasgow coma score of E1 M3 V1. Soon after, she developed a respiratory arrest and was intubated. A posterior fossa hematoma was considered at this point; therefore she was rushed to the OR for re-exploration. No CT scan was done before the patient was taken to theatre. At surgery, the cerebellum was found to be contused and bulging, but no hematoma was found. The lateral third of the cerebellum was excised, and wound was closed leaving the dura open. After the surgery she was transferred to ICU and ventilated. A CT scan showed hypointensity in the cerebellum and brainstem suggestive of an infarct with obliteration of the fourth ventricle and dilated lateral and third ventricles. An external ventricular drain was inserted and a tracheostomy was done. The prognosis was explained to the relatives and they decided to take her home.

The external ventricular drain was removed; she was weaned off the ventilator and discharged with a Glasgow coma score of 3t /15. She expired later at home.

There were three patients from the aggressive group who developed brainstem dysfunction. One patient (Case no 40 – refer data sheet) underwent a combined supra and infratentorial presigmod approach for a right petroclival meningioma. At surgery, the pons was markedly compressed and the plane with the pons was not good. The basilar artery, right superior cerebellar artery and posterior cerebral arteries were encased by the tumour. A thin rim of tumour on the pons and midbrain above the 5th root entry zone and around the basilar artery and its encased branches was left behind. Both the bone work and the tumour excision were done by a single team, in one sitting. The duration of surgery was 13 hours. The patient was transferred to the ICU for elective ventilation, but in the immediate postoperative period it was noticed that the patient had a non-reacting pupil on the right side. A CT scan on the first postoperative day showed a hypodensity in the pons, midbrain and right thalamus and a 2 x 1.5 cm right cerebellar hematoma with no mass effect. A brainstem infarct was considered probably due to perforator injury. Her Glasgow coma score did not improve after the paralysis and sedation was stopped. She underwent a tracheostomy, was started on Ryles tube feeds and discharged with a Glasgow coma score of 4t/15.

Another patient (Case no: 38 - refer data sheet) underwent the combined supra and infratentorial presigmoid approach and subtotal excision of a right sided petroclival meningioma. At surgery, it was seen that the tumour had a poor plane with the brainstem. The part in the cavernous sinus was left behind. She was not reversed in theatre as per the surgeon's instructions and was electively ventilated in the ICU. It was noticed that she developed a left hemiparesis with worsening of right sided 5th, 7th, 8th and 9th, 10th cranial nerves. A CT scan showed the residual lesion in the cavernous sinus region and dilatation of the left lateral ventricle with periventricular lucencies. An external ventricular drain was inserted for 5 days and removed when her GCS had improved to 9t/15. She did not require a shunt. She was started on nasogastric feeds and the tracheostomy was closed. She was discharged with a GCS score of 12/15. None of these patients had further follow- up.

The last patient (Case no: 36 - refer data sheet) underwent a radical excision via a combined supratentorial and infratentorial presigmoid approach. At surgery the plane with the brainstem was good and the tumour was totally excised except for a part which was going into the jugular foramen. There was bleeding from a branch of the vertebral artery that was controlled. The duration of surgery was 10 hours. He was ventilated overnight and was extubated the next morning. He did not maintain his airway and therefore he was re-intubated and ventilated. A CT scan showed moderate ventricular dilatation and a hypodensity in the left cerebellum and dorsal pons. He had a left gaze paresis and right hemiparesis in addition to worsening of 9th, 10th

cranial nerve function. He went on to develop a chest infection and expired on the 17th postoperative day.

Table 3 compares the incidence of complications in the aggressive and conservative group. There was one mortality in the aggressive group. A total of 14/41(34.14%) patients had morbidity after excluding the transient cranial nerve deficits. Eight of 22 (36.4%) patients in the aggressive group had morbidity and six of 19(31.6%) in the conservative group had morbidity. The risk of developing morbidity was 1.23 times higher in the aggressive group.

Radiation therapy (RT):

Twenty four patients underwent conventional radiation therapy, 6 had stereotactic radiotherapy (SRT) and 1 patient had stereotactic radiosurgery. The 10 patients who did not undergo RT were those 4 patients who had a poor outcome and six patients in the aggressive surgery group. One patient (Case no: 34 – refer data sheet), who had a radical excision, underwent stereotactic radiotherapy since the biopsy was an atypical meningioma WHO grade 2. During radiation, one patient (Case no: 35 - refer data sheet) developed hyponatremia and required readmission. This patient had CT evidence of tumour in the suprasellar region and hypocortisolemia. Another patient (Case no: 11 - refer data sheet) developed cerebral salt wasting, hyponatremia and seizures and had to be readmitted. Both patients improved with intravenous sodium correction, and were discharged with normal sodium levels.

Follow up:

Follow up was available in 34 patients (82.9%) with a median of 36 months (Range 10 -107 months). These patients were analyzed as two groups, those who underwent aggressive surgery and those who underwent a conservative surgery.

Evaluation of functional outcome: **(see table 4)**

a. Aggressive group:

Of the 22 patients who had an aggressive surgery, 4 were lost to follow up and one died leaving 17 available for follow up. Mean follow up time was 28.3 months. Of these, 4 patients had poor outcome, 5 patients required assistance for activities of daily life while 8 were independent for activities of daily living.

One patient (case no: 4) who had undergone a subtotal excision had evidence of growth of the residual tumour 7 years later. Her biopsy at the time of surgery was angiomatous meningioma. She was advised to undergo SRT, but did not, until 2003, during which time a CT scan done showed a 2.5 x 1 cm recurrence at the right petrous apex region as an extension of the residual tumour. She received SRT and 2 years later, she was stable with the tumour showing no size of further growth on the CT scan. One patient who had undergone radical resection of his tumour underwent SRT since the biopsy was an atypical meningioma. He was stable at 36 months follow up with no evidence of tumour on the CT scan.

b. Conservative group:

Of the 19 patients who underwent a partial excision or biopsy, 3 were lost to follow up and out of the 16 available patients, 1 had a poor outcome.

Three patients (18.8%) required assistance for activities of daily living while 12 (75 %) were independent. All patients in this group underwent radiation. One patient had evidence of tumour growth, three years after radiation but was not operated because of medical risk factors and since he was already dependent for activities of daily living.

Five (31.2%) patients had decrease in tumour size with radiation therapy with an average follow up period of 71.5 months (range 42 – 104 months, median 67.5 months). Ten patients had no evidence of tumour growth.

Comparison of outcome between the aggressive and conservative groups:

Table 4 shows a comparison of outcome between the aggressive and conservative groups. It is seen that, these two groups were similar with respect to age, gender, risk factors and tumour size with no statistically significant difference of distribution in these factors. The risk for developing morbidity in the aggressive group compared to the conservative group was 1.23 (95 % Confidence interval 0.3 - 5.6, p value 0.87), the risk of developing a poor outcome in the aggressive group was 4.6 (95% Confidence interval 0.4 - 242.1 p value 0.17). When mortality and poor outcome was combined and analyzed, (since patients with poor outcome were likely to have expired

elsewhere) the risk in aggressive group was 5.3 times greater (95% Confidence interval 0.5- 263.1 p value 0.11)

Tumour calcification after radiotherapy:

Of the 19 patients who had undergone conservative surgery with radiation, six had evidence of calcification in their tumours. Of these five had no evidence of calcification in their preoperative scans. The average onset of calcification was seen from 3-4 years. Five patients had decrease in size of the tumour while one remained to be the same size. (See appendix III) The calcification seen in the scans ranged from partial calcification of the lesion along the periphery of the tumour to just a solid lump of calcium seen instead of the tumour. However none of these patients had any clinical evidence of disease progression and were leading a normal life, independent for activities of daily life.

RESULTS - TABLES

Table 1- A comparison of age, gender distribution and preoperative deficits with respect to the tumour size in 41 patients with petroclival meningiomas.

Tumour size	Age (years)		Gender		Deficits			
	<50	>50	Male	Female	Cranial Nerve	Hemiparesis	Ataxia	Raised intracranial pressure
2-4 cm N = 10	5	5	2	9	9	8	9	7
>4cm N = 31	25	6	8	22	30	13	18	18
Total 41	30	11	10	31	39	21	27	25

Table- 2 showing the correlation between the extent of resection, tumour size and approach used in 41 patients with petroclival meningiomas.

Aggressive N = 22				Conservative N = 19		
	Tumour size			Tumour size		
Approach	2-4 cm	>4cm	Total	2-4 cm	> 4 cm	Total
Retromastoid	2	4	6	4	3	7
Combined supra and infra presigmoid	4	8	12	0	6	6
Fronto-temporal	0	3	3	0	6	6
Combined anterior and posterior transpetrosal	0	1	1	0	0	0

Table 3 Complications and outcome in aggressive and conservative groups after surgery

Morbidity (transient deficits excluded)	**Aggressive(N=22)** **(8/22 – 36.4%)**	**Conservative (N=19)** **(6/19- 31.6 %)**	**Odds ratio and p value for total morbidity**
Worsening of cranial nerves	1	2	1.23 95% CI 0.3 – 5.6) p value 0.87
Hemiparesis	0	0	
CSF wound leak	2	2 (1 had permanent 9^{th} 10^{th})	
CSF otorrhea	1	1	
Temporal lobe hematoma	2	0	
Cerebellar infarct or hematoma	0	2(1 had brainstem dysfunction)	
Brainstem dysfunction	2	1	

Table - 4 Comparison of various factors including the baseline factors and outcome between patients who underwent an aggressive surgery vs conservative surgery

Variable	Aggressive surgery (n=22)	Conservative surgery (n=19)	Statistical analysis	
			"T"/ chi square value	p value
Age (mean)	43.7	45.3	0.57	0.56
Gender male female	6 16	4 15	0.21	0.64
Risk factors				
Diabetes mellitus	2	5	0.51	0.41
Hypertension	5	6		
Tumour size				
<2	0	0		
2-4	6	4	0.21	0.64
>4 cm	16	15		
Quality of life				
Dependant - for activities of daily life	6	7	0.43	0.51
Independent - for activities of daily life	16	12		
Outcome				
a. Mortality	1	0		
b. Postoperative morbidity	8	6	Odds ratio 1.23 95%CI (0.3-5.6)	0.87
c. Poor outcome	4	1	Odds ratio 4.6 95%CI (0.4-242)	0.21
d. Morbidity + mortality	9	6	Odds ratio 1.5 95%CI (0.4-6.7)	0.54
e. Mortality + poor outcome	5	1	Odds ratio 5.3 95%CI (0.5-263)	0.11

DISCUSSION

Petroclival meningiomas pose a formidable challenge to any surgeon, considering their location and the neurovascular structures in their vicinity. The decision as to how to treat patients with these tumors is difficult, because of varied treatment options, rarity of the tumor and its variable biological behavior. The major question is whether all tumors, should be radically resected despite the possible risk of severe permanent neurological deficit. For the reasons mentioned above, the ideal treatment for these tumours is continuously under discussion. Our study was a retrospective review of 41 petroclival meningiomas operated from 1995-2005. As with most of the other series[4-8, 9-11] we observed that these tumours were more common in the female gender (75 percent). The mean age in our series was 44.5 years which was also comparable to other studies. Tumour size varied from less than 2 to more than 6 cm across major studies with a few authors[9, 10] reporting series in which tumours >4.5 cm contributed to 65 % of their cases. Other studies reported an almost equal distribution of larger tumours (more than 3.5- 4 cm) and smaller tumours (less than 3 cm) [3,5-8]. In our series, we observed, that 75 % of tumours were above 4 cm while there were no tumours below 2 cm. The fact that petroclival tumours are slow growing and produce noteworthy symptoms only once they have attained a large size maybe the reason why larger tumours form the majority [3]. Smaller tumours usually present with isolated sixth nerve palsy or a subtle trigeminal nerve deficit; therefore an astute physician on detecting these signs should order for a CT/ MRI brain.

We found that about 73% of the tumours were more than 4 cm in those patients less than 50 years of age. This association of young age and accelerated growth rate is supported by other authors[9] who found that growth rates in petroclival meningiomas range had significant correlations between lower growth rates, and old age and the onset of menopause.

We found that the most common presenting symptoms in our series were imbalance of gait affecting 27/41 patients (65.8%) or headache 25/41(61%), whereas cranial nerve deficits represented the most common presenting signs 39/41 (95%), the facial nerve in 33/41 patients (80.5%), and the trigeminal nerve in 29/41 (70.7%), being the most common cranial nerves affected. Twenty-one (51.2%) had evidence of long tract signs in the form of hemiparesis or hemisensory loss. Twenty five (61%) had evidence of raised intracranial pressure as evidenced by papilledema. The common neurological findings associated with this tumour in other reported series are cranial nerve involvement which varied from 37-67%, ataxia (14-90%) and long tract involvement (3-41%) [3-13.]

The higher incidence of raised intracranial pressure and long tract signs (>50 %) is probably related to the fact that 75 % of our cases had tumors larger than 4 cm. Although larger tumours tended to produce deficits more frequently than smaller tumours, this difference was not statistically significant.

Treatment options for Petroclival meningiomas:

The results of recent publications showing a good long term outcome after subtotal surgery with stereotactic radiotherapy have provided new insights into the optimal management of these tumours. It is clear that complete resection is

theoretically the optimal treatment especially if surgery could be performed with negligible morbidity and no risk of death[7]. However, a review of recent series of petroclival meningiomas [3,5-12,29,36,38] reveals a reduced mortality and morbidity rates with good quality of life at follow up, by authors who advocate a less radical approach[4,9,12,29,36]. In our series we addressed this issue by comparing the outcomes in patients undergoing aggressive surgery with those undergoing conservative surgery with radiation. Twenty-two patients (53.66%) underwent an aggressive surgery while 19 (46.34%) underwent conservative surgery and radiation therapy. The overall mortality rate was 2.4 percent and morbidity was 34.14 % with 12.2 % developing poor outcome. Fifty-one percent had long tract signs, and 7.3 % had permanent cranial nerve deficits. We found that the risk for developing a poor outcome was 4.6 times greater in the aggressive surgery group compared to the conservative surgery group, although this did not reach statistical significance. Major morbidities such as brainstem dysfunction, temporal lobe hematomas and death occurred with greater frequency in the aggressive surgery group as compared to the conservative group in whom there was only one case of brainstem dysfunction and no mortality.

Recently published reports [3,5-11,25] state that the likelihood of complete resection varies from 26 to 79%. These studies also describe a significant morbidity associated with a radical surgical intervention. From 2 to 10% of patients die as a direct result of surgery while poor outcome such as persistent vegetative state has been reported in 12 to 27% of patients. The risk of hemiparesis varies from 7 to 45%, and permanent cranial nerve deficits resulting

from surgery were noted in 22 to 91% of patients. However with a revised goal of surgery, the morbidity and mortality of surgery was reduced to a significant degree.[4,9,12,29,36.] Abdel aziz et al[4] reported only 37 % of gross total resection, but with no mortality, 9 % morbidity and 31 % new cranial nerve deficit. These authors used radiotherapy as an adjunct for patients who had an incomplete resection of their tumours and report a 3 % recurrence at a mean follow up of 50 months.

Adjuvant radiation therapy:

Recent studies have demonstrated improved outcome and survival rates in patients undergoing subtotal resection with radiation therapy[14-21]. These studies have determined a 10-year progression-free survival of 18% after subtotal resection alone, 77% after gross total resection, and 82% after subtotal resection plus radiation therapy. Jung et al[9] found that the growth rate of subtotally resected tumours (0.37 to 4.94 cm^3/year) was more what was seen in non-operated meningiomas (0.81 cm^3/year). This underlines the need for radiotherapy in partially resected tumours. In general, tumor control rates after subtotal resection and fractionated radiation therapy range from 72 to 95%, with variable lengths of follow-up[14-17, 19-21]. Studies[29, 37] which compared results of surgery alone with surgery and radiation as well as radiosurgery as primary treatment conclude that, in tumours less than 3 cm, as well as in old patients with multiple morbidities, radiosurgery is a better option to operative intervention because excellent tumour control has been demonstrated in tumours less than 3 cm while after weighing the advantages and disadvantages, radiosurgery has been shown to have a clear edge over surgery in old patients with multiple morbidities. Our data also showed

that postoperative radiotherapy was effective in controlling the growth of residual tumors in the 31 patients who underwent this treatment. Twenty four patients had conventional radiotherapy, 6 had stereotactic radiotherapy and one had stereotactic radiosurgery. These patients had a mean follow up of 38 months. There was one recurrence.

Surgical approaches:

In our series, we used the retromastoid, frontotemporal, combined supra and infratentorial presigmoid and combined anterior and posterior transpetrosal approaches. The 2-4 cm tumours were operated through the retromastoid or combined supra and infratentorial approach while tumours more than 4 cm were operated via all the four approaches, mentioned above. The 41 patients in our series were operated by 5 surgeons. The choice of approach and the aggressiveness of resection depended on the patient characteristics like tumour size, associated medical risk factors and the surgeon's comfort levels, learning curve and policy.

A surgeon who operates on only one or two petroclival meningiomas a year cannot clearly do justice to these tumours. On the other hand, with subspecialisation, petroclival meningiomas would be operated by one team, thus they would be able to improve their skills and formulate appropriate treatment protocols. This is one way of improving the outcome in these tumours and is recognized by the neurosurgical community[53]. Albright et al conducted a study where neurosurgeons were classified as general neurosurgeons, as designated pediatric neurosurgeons in their institutions, or as members of the American

Society of Pediatric Neurosurgeons (ASPN), which requires pediatric neurosurgical experience and practice standards. The mean number of operations per surgeon was 1.8, 4.9, and 7.6 for general neurosurgeons, designated pediatric neurosurgeons, and ASPN members, respectively. There was a significant relationship between the extent of tumor resection or the amount of residual tumor and the type of neurosurgeon. Designated pediatric neurosurgeons and ASPN members were more likely to remove more than 90% of the tumor. In these studies, the probability of extensive tumor removal correlated with the number of operations the neurosurgeon did. Complications also were more for general and designated pediatric neurosurgeons compared to the ASPN members. Thus the patient outcome was much better when a neurosurgeon who was trained in pediatric neurosurgery, operated on them. This clearly outlines the need for sub specialization in neurosurgery.

The various approaches used for petroclival meningiomas range from the classical retromastoid approaches, the middle fossa approaches and modifications, and more recently the transpetrosal approaches. The combined anterior and posterior transpetrosal approach described by Hakuba[39] is a recent addition to our range of approaches. We find that, this approach provides an excellent and wide exposure for large tumours extending from below the internal auditory meatus, and having a large supratentorial and middle fossa component.

Although the retromastoid approach is simple with good exposure of the posterior petrous surface, the surgeon needs to work through the narrow corridor between the cranial nerves and moreover, the exposure of midline tumour is

difficult. However, if the preoperative plan is just a partial resection, or a generous biopsy, this is a good option since it is simple, requires no major bone work and has decreased chances of CSF leak. Goel et al[38] reported a case series of 28 patients operated by a posterior fossa route during the period 1991 to 2002 encompassing the lateral supracerebellar-infratentorial and retrosigmoid avenues. The maximum diameter of the tumors ranged from 1.8 to 6.8 cm (mean, 4.0 cm). The average length of follow-up was 48 months. They achieved gross total resection in 75% of patients with 7.1 % mortality rate and 42.9 % morbidity rate with one recurrence. None of the patients were radiated. These authors feel that conventional posterior cranial fossa surgery can be suitable for a select group of petroclival meningiomas and that it provides an easy and quick exposure of the tumor without any petrous bone drilling with direct and early exposure of the tumor-cranial nerve-brainstem interface. The other positive points they see with this approach are that the lateral and inferior tumor extensions in relationship to the clivus can be more easily accessed and the site of attachment of the tumor to the dura overlying the posterior face of the petrous apex can be seen directly.

In terms of exposure, the middle fossa approaches provides the shortest route to the tumour. Here, the cranial nerves are posterior to the tumour capsule and are encountered only after considerable debulking of the tumour. Moreover, this approach can be combined with a presigmoid exposure of the infratentorial portion of the tumour. Kawase et al[40] described the anterior petrosectomy that provides an excellent view of the tumour in the petroclival region. This is a good approach for a small tumour lying between the top of the clivus and the internal

auditory meatus. A significant advantage of Kawase's technique is that it provides an extradural approach to the petroclival region. On the other hand, the presigmoid supra-infratentorial approach requires retraction of the temporal lobe intradurally that predisposes to temporal contusions and vein of Labbe injury. Many variations of anterior petrosectomy have been described, and later this approach was combined with a posterior petrosectomy[39] to provide a comprehensive approach to petroclival meningiomas. A commonly observed problem associated with the transpetrosal / middle fossa approaches is the occurrence of CSF leaks due to the extensive skull base exposure opening into the middle ear and mastoid antrum. The incidence in our series was 12 % while in reported series it varied from 14 to 28% with various middle fossa or transpetrosal approaches[3,4,6,8,25,39,40,54]. Thus the closure for this approach necessitates waxing of the exposed bone and meticulous dural repair with a pedicled temporalis muscle, fascia and fibrin glue with a prophylactic lumbar subarachnoid drain.

Three of our patients in this series who developed brainstem dysfunction were operated by one team in a single stage surgery, the duration of surgery being more than 10 hours in all cases. Surgeon fatigue is an important consideration in these situations and these surgeries should probably be either staged or two separate teams should be involved in the surgery - one dealing with the bone work and the other with tumour excision.

Tumour calcification after radiation therapy:

Interestingly, we noted that there were 5 patients with tumours that developed calcification after radiation therapy. Studies regarding the natural

history of incidental and asymptomatic meningiomas have found a significant correlation between calcification and reduced tumour growth [55,56]. However, to our knowledge there is no literature regarding the development of tumour calcification in radiated tumours. These tumours were not calcified before radiation and the time to calcification after radiation varied from 1 to 4 years. Of significance is the fact that the growth of these calcified tumours appeared to be arrested and four even showed a decrease in size. It is likely that the appearance of dystrophic calcification in a tumour after radiation may indicate inactivity in tumour growth.

Dystrophic calcification refers to the macroscopic deposition of calcium salts in injured tissues and can range from gritty sand like grains to rock hard lumps of calcium. Calcium entry into dead or dying cells is probably due to the inability of such cells to maintain a steep calcium gradient[57] with the formation of a crystalline calcium phosphate mineral in the form of an apatite similar to the hydroxyapatite of the bone[57]. There are two phases involved in dystrophic calcification. The first is the initiation or nucleation followed by propagation. Both phases can occur intracellularly or extracellularly. Initiation of extracellular sites of calcification occurs in membrane bound vesicles about 200 nm in diameter. In cartilage and bone, they are known as matrix vesicles, and in dystrophic calcification they are derived from degenerating cells. Initiation of intracellular calcification occurs in the mitochondria of dead or dying cells that accumulate calcium. Subsequently, propagation of crystal formation occurs, dependent on the concentration of calcium and phosphate in the extra cellular spaces, in the presence of mineral inhibitors and collagen and other proteins. In addition

osteopontin, an acidic calcium binding phophoprotein with high affinity to hydroxyapatite, and known to be involved in bone mineralization, appears to be involved[57]. Since injured or dead tissues develop dystrophic calcification, it is logical to conclude that tumours which develop calcification maybe inactive and would have a good prognosis. This “dying out” of the lesion may be due to the radiation since these patients developed calcification 3-4 years after radiation.

Summary:

Petroclival meningiomas remain one of the most challenging intracranial tumours to treat surgically. Our results corroborate the fact that radical surgery for petroclival meningiomas is associated with significant mortality and morbidity and adjuvant radiation therapy is useful in preventing tumour progression in residual disease. These results may also suggest that conservative surgery with postoperative radiotherapy is a valid alternative to radical resection.

The present data on the natural history of petroclival meningiomas suggest that most of these tumours grow incessantly. Small and medium size tumours seem especially prone to more growth. Therefore, active treatment for symptomatic patients with small or medium sized tumors is mandatory. For younger patients, surgery is the treatment of choice; for elderly patients or patients who cannot undergo surgery, stereotactic radiosurgery may be proposed[29].

Although our follow-up periods are relatively short for a slow growing tumor such as meningioma, the current data is useful in determining the most appropriate treatment option in terms of the patient’s quality of life. We feel that,

although the mindset of the surgeon should be in favour of a radical resection as he embarks on the surgery, a conscious decision as to leave tumour behind should be made if operative conditions are not favorable. Stereotactic radiotherapy provides a good option in managing residual tumours.

CONCLUSION

Patients undergoing aggressive surgery for petroclival meningiomas have a poorer outcome than those undergoing partial excision with radiotherapy. We therefore recommend that, although the goal of surgery should be maximal cytoreduction, the surgeon should be content with leaving residual tumour on the brainstem, particularly when the tumour brainstem interface is poor. Radiation therapy is a good therapeutic option for patients with residual disease after partial excisions.

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APPENDIX - II

ILLUSTRATIVE CASES – 1 (case no: 36 Data sheet)

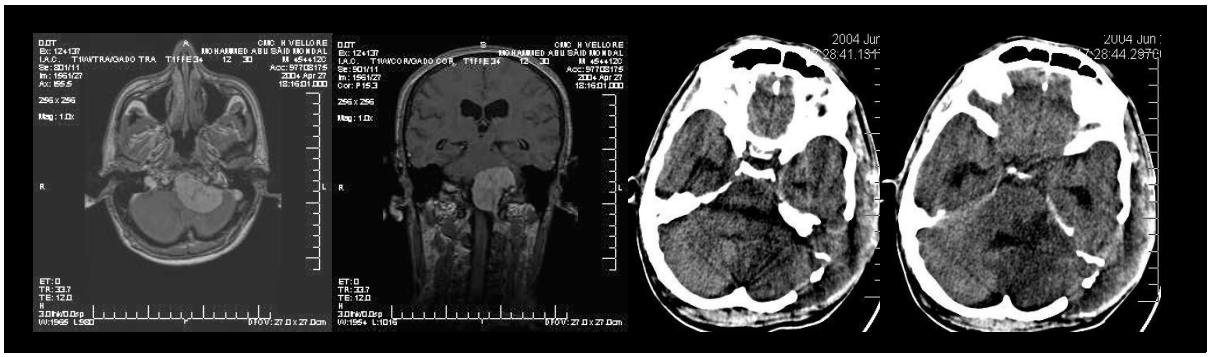

Figure 1a **Figure 1b**

Fig1a - Axial and coronal gadolinium enhanced MRI scans of a 49 year old man who presented with left hemiparesis, 9th, 10th paresis on the left, and ataxia show a 4.7 x 4.1 x 3 cm petroclival meningioma. There was evidence of gross brainstem compression **Fig 1b** Post Operative CT Scan following a radical excision via a combined supra and infratentorial presigmoid route, showing no residual tumour. This patient had a poor outcome with brainstem dysfunction and death after two weeks.

Case 2 (Case 39 –Datasheet)

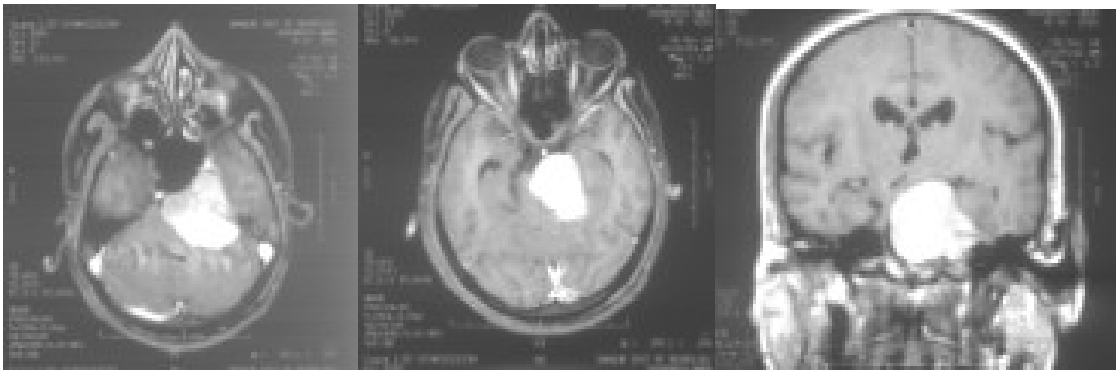

Figure 1 Contrast enhanced MRI scans (axial and coronal series shown) of a 41 year old man who presented with headache suggestive of raised intracranial pressure, left hemiparesis and left 5th and 7th nerve paresis on the left side.) showed a 4.5 x 4 x 3cm contrast enhancing left petroclival lesion.

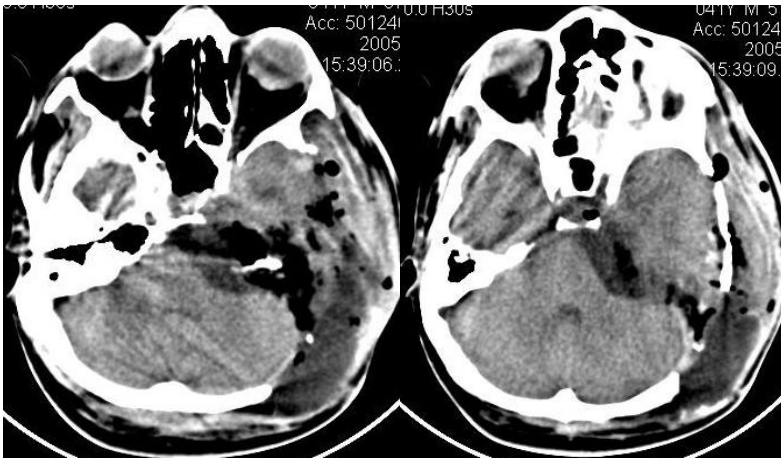

Figure 2 Immediate postoperative CT scans showing the bone drilling used for combined transpetrosal approach and no evidence of residual tumour. This

patient underwent a radical excision via the combined anterior and posterior transpetrosal approach.

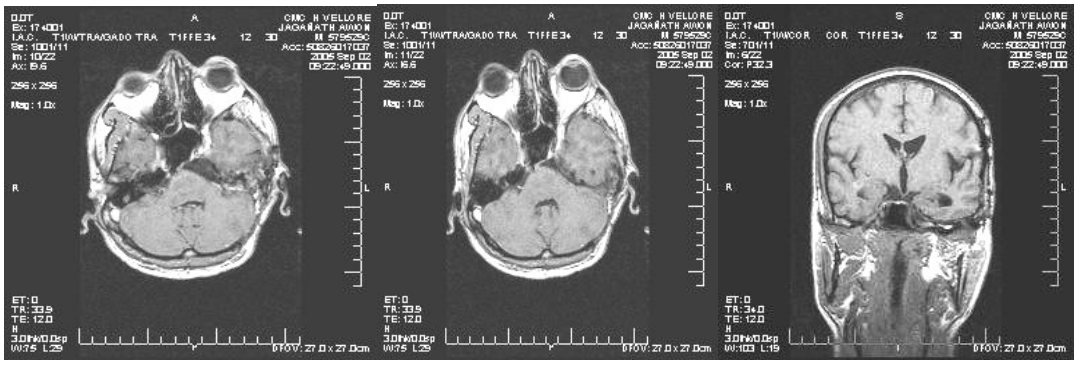

Fig 3 shows 9 months postoperative CT scans. He was doing well at 18 months follow up and was independent for ADL. This approach is technically demanding, but rewards a beautiful exposure.

Case -3 (Case 37–Datasheet)

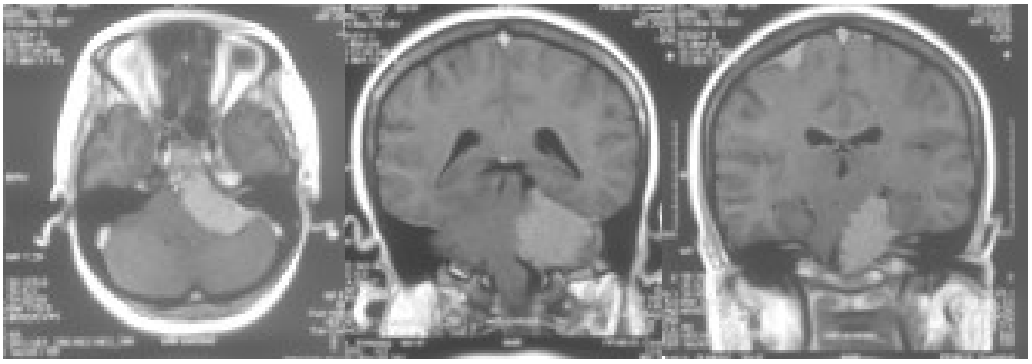

Fig 1. Preoperative contrast enhanced MRI scans (axial and coronal scans shown) of a 38 year woman who presented with left sided 5th, 8th and 9,10th paresis showing a 4.5 x 4 x 3 cm lesion in the left petroclival region. Also note that she had a 1 cm left parietal convexity meningioma.

Fig 2a **Fig 2b**

She underwent a radical excision through a retrosigmoid approach **Fig 2a** immediate postoperative CT scan showing the bone removal done and no residual tumour. **Fig 2 b** Contrast enhanced MRI scans (axial and coronal cuts) at one year follow up. There was no evidence of recurrent or residual tumour

APPENDIX - III

Patients who developed calcification

CASE – 1 (Case 25 –Datasheet)

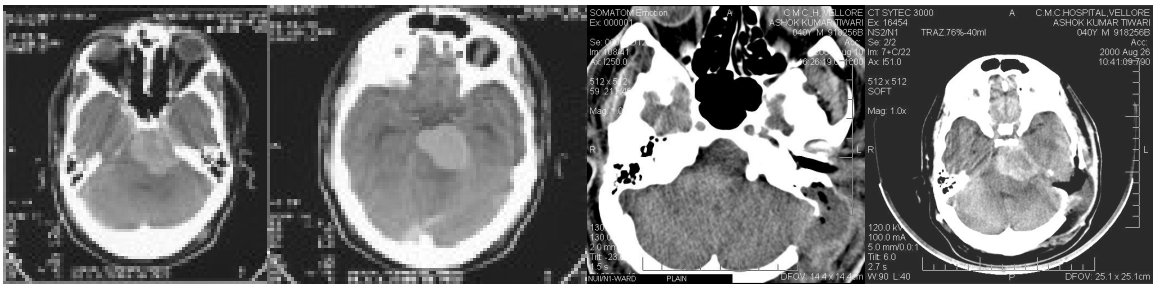

Fig 1 a **Fig 1b**

Fig 1a Contrast enhanced axial CT scans of a 40 year old male patient who presented with headache and left 3rd 5th and 6th paresis showing a 4.5 x 4 cm lesion in the left petroclival region. This patient was underwent partial excision and RT. **Fig 1b** showing axial CT scans in the immediate postoperative period showing partial resection.

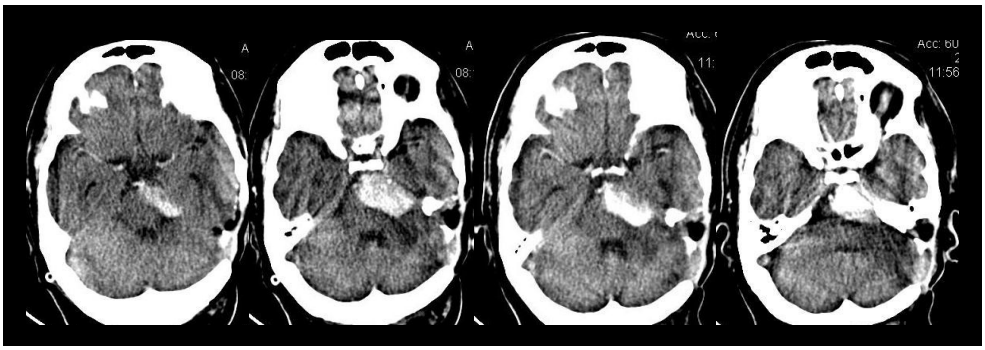

Fig 2a **Fig 2b**

Fig 2a and 2b shows axial CT scans of petroclival region at 4 year follow up and 6 year follow up. This is an example of stable disease. Note that the tumour has decreased in size and has also developed calcification.

Case 2 (Case 2 –Datasheet)

Fig 1

Fig 1 showing axial contrast scans of a 40 year old female patient who presented with headache, right sided fifth and seventh nerve paresis. Description of preoperative scans in the documents was suggestive of calcification in the preoperative period itself. She underwent a partial excision, and stereotactic radiosurgery. At surgery, her tumour was found to be having a calcific component. The scans shown above shows the lesion at 7 year follow up. She remains independent for activities of daily life. Here again, the tumour seems to be a calcific mass, which probably “died out”.

Case 3 (Case 20 –Datasheet)

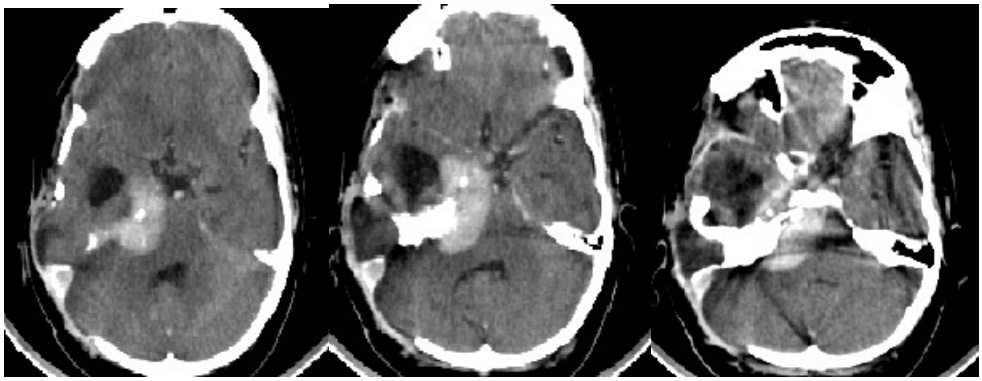

Fig 1 showing axial contrast scans of the petroclival region in the immediate postoperative period of a 27 year old woman who presented with headache and cranial nerve 5th, 7th involvement on the right side. Preoperative scans were not available. She underwent a combined supratentorial/infratentorial approach and partial excision of the lesion.

Fig 2 Axial contrast scans of the petroclival region in the same patient 3 years postoperatively showing reduction of size in the residual lesion and calcification in the lesion. She remains independent for activities of daily life at 42 months follow up.

Case 4 (Case 12 –Datasheet)

Fig 1 showing axial contrast scans showing a left petroclival lesion 5.5 x 5 x 4 cm lesion in a 51 year old female who presented with headache, ataxia and cranial nerve 5th, 7th involvement. She had hydrocephalus for which she was shunted in the preoperative period. She underwent a retrosigmoid approach and partial excision of the lesion followed by radiation.

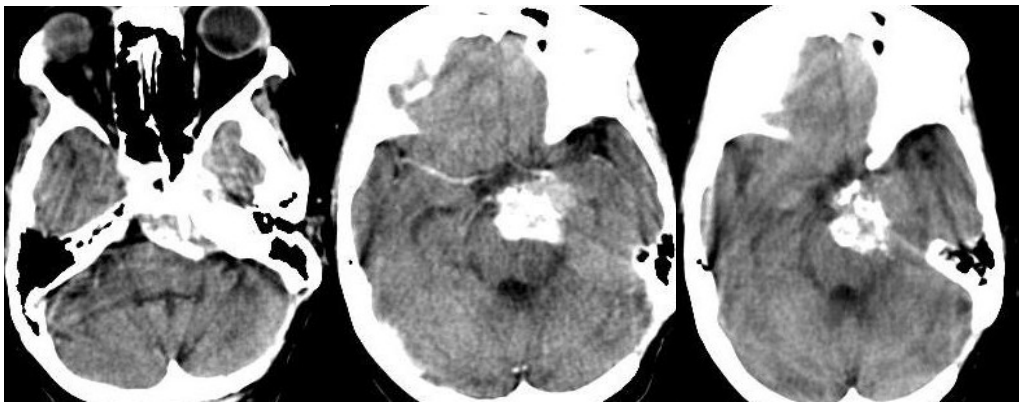

Fig 2 showing axial contrast CT scans of the same patient 7 years postop. The residual tumour size has decreased and there is dense calcification seen within

the tumour. This patient was stable at 7 year follow up with no clinical evidence to suggest progression of the disease.

Case 5 (Case 22 –Datasheet)

Fig 1 showing immediate postoperative axial contrast CT scans in a 37 year old female who presented with headache, and cranial nerve involvement 5, 7, 8. She had undergone a frontotemporal approach and partial excision of a petroclival meningioma.

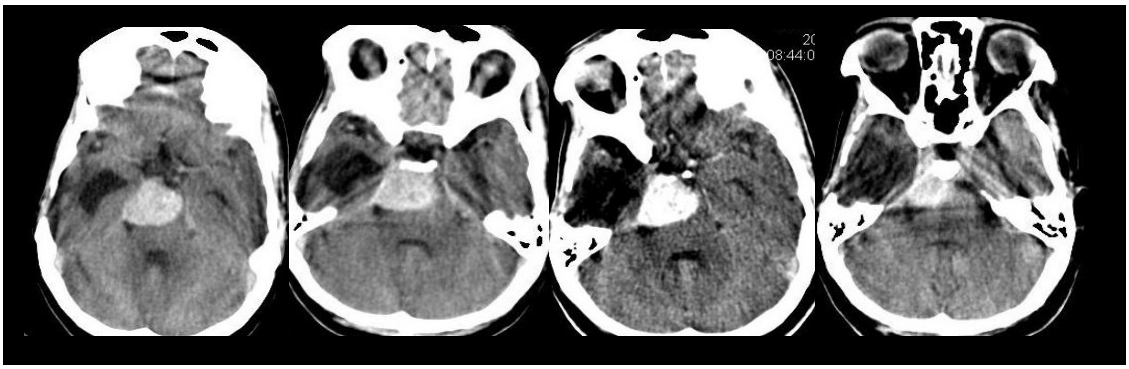

Fig 2 a **Fig 2b**

Fig 2a and **Fig 2b** showing 1 year post op and 5 year post op scans in the same patient. Note that, in the five year postoperative scans there is evidence of calcification. This patient was stable at 5 year follow up.

Case 6 (Case 17 –Datasheet)

Fig 1a **Fig 1b**

Fig 1 a and **1 b** shows 4 year postoperative and & 7year postoperative axial contrast enhanced CT scans in a 45 year old lady who presented with headache. She underwent a combined supratentorial/infratentorial approach and partial excision of the lesion. Both scans show evidence of calcification in the part below the IAM. At 7 year follow up she was independent for activities of daily life and had no clinical evidence of disease progression.